

National Aeronautics and Space Administration
Small Aircraft Transportation System (SATS)
Program Planning White Paper
September 19, 2000

I. Introduction

This white paper briefly outlines the SATS Vision, the proposed NASA SATS research Program, and the relationships between SATS research and challenges facing the FAA in the National Airspace System. The SATS Program is planned as a proof-of-concept five-year, \$69 million effort starting in FY 2001. The program planning is focused on developing six key technologies to support the creation and demonstration of three innovative operational capabilities. The outcome of the five-year proof of concept includes experimental data from flight and simulation demonstrations as well as analysis of the implications of technologies in transportation system decision-making. In the nearer term, the initial SATS operating capabilities have the potential to create a complementary strategy for responding to the challenges of growth of National Airspace System (NAS) capacity, the cost of NAS expansion, and the demand for increased throughput in the NAS. In the farther term, the SATS technology investments create a potentially new alternative transportation choice for addressing the nation's challenge of unmet transportation demand related to the spreading of congestion on highways and in the major airport system.

II. Definitions, and Background

The NASA Aerospace Technology Enterprise goal is to reduce inter-city travel times for U.S. citizens by half in 10 years and by two-thirds in 25 years. The Small Aircraft Transportation System (SATS) concept supports this goal as a long-range transportation system vision with technical objectives spanning 25 years. The vision encompasses three phases of roughly a decade each in length to fully develop a SATS in the United States.

- Small: The technologies targeted for development are aimed at smaller aircraft used for personal and business transportation missions within the infrastructure of smaller airports throughout the nation. These missions include travel by individuals, families, or groups of business associates. Consequently the aircraft are of similar size to typical automobiles and vans used for non-commercial ground transportation – two to eight seats. They may be used for on demand, unscheduled air-taxi transportation of these same user types. Various forms of shared ownership and usage will likely be a most common means of use. While the aircraft are not specifically designed for air carrier use, the targeted technologies would provide benefits to commuter and major air carrier operations in the hub-and-spoke system as well. For FAA regulatory purposes, SATS technologies are targeted toward aircraft with a maximum take off weight (MTOW) less than 12,500 pounds (*i.e.*, FAA small aircraft category).

- Aircraft: The strategy for development of airborne technologies focuses initially on fixed-wing airplane applications; however, the technologies created are also applicable to operational improvements for vertical take-off and landing aircraft. These technologies would enable near all-weather operations by new generations of such aircraft at virtually any landing facility in the nation. Near all-weather means operational reliability in instrument meteorological conditions except those classified as severe or hazardous (i.e., severe icing, severe turbulence, thunder storm activity, etc).
- Transportation: The technology investments are selected and prioritized for the purpose of transportation of people, goods, and services. Even so, the technologies would likely have favorable effects on safety, cost, and accessibility in recreational or other non-transportation commercial uses. The aircraft will have the altitude and speed performance, as well as the weather avoidance and toleration systems, to enable safe and reliable operations with high availability (similar to or better than today's air carrier reliability).
- System: In addition to technologies for the aircraft, SATS strategies are conceived to affect the nature of aviation operational capabilities for airports, airspace, and air traffic and commercial services. The SATS vision encompasses inter-modal connectivity between public and private, air and ground modes of travel. In concept, the SATS vision integrates the use of smaller landing facilities with the interstate highway system, intra-city rail transit systems, and hub-and-spoke airports. The strategy focuses on airborne technologies that expand the use of airports with excess capacity (those without precision instrument approaches) as well as underutilized, unmanaged airspace for transportation use (such as the low-altitude, non-radar airspace below 6,000 feet and the enroute structure below 18,000 feet).

III. SATS Proof of Concept Program:

A five-year proof of concept research effort is planned to develop the key technologies needed for an initial set of four SATS operating capabilities. The proof of concept program would culminate in a joint NASA/FAA demonstration of these SATS operational capabilities. The SATS Program planning is linked to the premise that reduced inter-city travel times is proportional to accessibility. The linked five-year program objective is to demonstrate key airborne technologies for precise guidance in three dimensions as well as in time, in small aircraft¹ to virtually any touchdown zone at small airports². These airports shall not require air traffic control towers and the airspace shall not require radar surveillance for air traffic services. The outcome of these objectives is to create expanded accessibility to virtually any landing site throughout the nation.

¹ FAA FAR Part 23 Certification, compliant to certitude standards in Advisory Circulars 23.1309 and 23.1311 for aircraft of less than 6,000 lbs. Gross Takeoff Weight (GTW) or 12,500 GTW; operated under FAR Part 91 or 135 regulations, with pilot training under FAR Part 141 including FAA approved waivers for the AGATE Unified Instrument-Private Pilot curriculum and Practical Test Standard

² General Aviation, Reliever, Regional, or Utility Landing Facilities of between 3,000 and 5,000 feet runway length or longer, without FAA FAR Part 139 regulatory requirements.

The SATS operational capabilities include (but are not limited to):

Higher Volume Operations at Non-Towered/Non-Radar Airports, in Unmanaged Airspace and EnRoute. Simultaneous operations by multiple aircraft in non-radar airspace at and around small non-towered airports can create accessibility to virtually any landing site in the nation in near all-weather conditions. This SATS operating capability has the potential to simplify the expansion of NAS capacity into unmanaged airspace and to increase Air Traffic Control (ATC) sector capacity. Maximum ATC sector loading decreases with complex (direct) flows, slower (Mach 0.5) airplanes, more traffic, and with demands for greater throughput. SATS research would propose to develop airborne technologies to enable the use of airspace between 13,000 and 24,000. The objective metrics for this capability include a minimum success requirement of at least two simultaneous aircraft operations in Instrument Meteorological Conditions (IMC) in the subject airspace. The research will also establish practical upper limits for numbers of aircraft in simultaneous operation in IMC at these facilities.

Lower Landing Minimums at Minimally Equipped Landing Facilities. Runway Protection Zones for Highway in the Sky graphical flightpath guidance can create near all-weather access to any touchdown zone at any landing facility while avoiding:

- Land acquisition costs
 - Approach lighting costs
 - Ground-based precision guidance systems (Instrument Landing System – ILS) costs
 - Radar and control tower infrastructure, operational, and maintenance costs
- This SATS operating capability can provide a low-cost approach to increasing NAS capacity. The objective metrics for this capability include a minimum success requirement for a reduction of approach minimums for visibility and cloud ceiling to better than those for typical Instrument Landing Systems (ILS) and better than existing Runway Protection Zone (RPZ) gradients of 50:1. The goal success requirement is for less than 1/4-mile visibility with no minimum ceiling requirement and less than 20:1 RPZ gradients.

Flight Systems for Improved Total System Performance. Human-aiding automation will provide intuitive, easy to follow flight path guidance superimposed on a depiction of the outside world. For example, photo-realistic database terrain can be graphically integrated with on-board sensing of terrain. Software enabled flight controls and flight planning can increase single-crew operational safety and mission reliability to two-crew levels. This SATS operating capability can lead to higher levels of safety and throughput for increasing numbers of users in the NAS. The objective metrics for this capability include a minimum success requirement of improving Total System Performance for a single-crew-operated aircraft by at least 25-percent than that of a two-crew-operated aircraft. The goal success requirement is to improve pilot-vehicle FTE performance in a single-crew-operated aircraft by more than 50%, while operating in IMC to the minimums and separation

requirements of the other operating capabilities. The resulting FTE improvements would be translated into reduced separation standards for such aircraft.

EnRoute Procedures & Systems for Integrated Fleet Operations. A fourth operational capability associated with integration of SATS aircraft into a higher en route capacity air traffic control system with complex flows and slower aircraft is being developed for the SATS proof of concept program.

IV. Technical Approach

The technical approach for the SATS research program includes laboratory, simulation, and flight experiments that integrate the enabling technologies discussed below to create and demonstrate the three SATS operating capabilities. The planned experiments will produce data on the ability of the SATS technologies to satisfy requirements for aircraft separation standards. These standards will apply in the targeted airspace, while meeting reduced Runway Protection Zone gradient requirements, supported by allocation of functions in the client-server architecture, within the limits of human-aiding automation in all aspects of flight control including separation and sequencing operations. In addition, the program must include partnership with the FAA to address the issues associated with innovations in certification of the technologies. The SATS Program products are intended to lead to development of the design guidelines, systems standards, and identification of certification issues for the enabling technologies and operating capabilities, while not resolving these issues.

Several new and emerging technologies will be further developed in the SATS Program to enable each of these four operational capabilities. These enabling technologies will be developed and integrated to create and demonstrate the SATS operating capabilities. The enabling technologies include:

- **Self-Sequencing and Separation Systems:** SATS research will include the development and testing of systems and algorithms that enable classless, self-organizing airspace operations. SATS will demonstrate the software-based ability for collaborative decision making between vehicles (clients) for dynamic generation of conflict-free flight path guidance.
- **Airborne Internet:** SATS will leverage open standards and protocols for a client-server network system architecture that are in development in the telecommunications industry for increased bandwidth for mobile applications. SATS research will leverage the developments in NASA and FAA Airspace System Capacity (ASC) research on Distributed Air Ground (DAG) collaborative decision-making. SATS research will focus on defining the functional allocations between clients and servers for all navigation, communications, and surveillance information necessary for aircraft operations including sequencing, separation, and conflict resolution.
- **Software-enabled Controls:** SATS research will integrate simplified flight controls and autopilot functions with new graphical display system architectures. The objective will be to reduce the complexity of interactions between aircraft attitudes, power settings,

and rates of motion, to limit flightpath to avoid loss of control, and to increase compliance of flightpath to clearances and traffic separation requirements.

- Emergency Autoland: SATS research will leverage the existence of the AGATE flight systems computerized architecture to create a computer-based flight control system for fail-safe recovery of aircraft and occupants following pilot incapacitation or other emergency situations. The SATS Program will include assessment of certification issues and requirements as well as aggressive constraints on cost goals for the SATS aircraft.
- Highway-In-The-Sky Guidance: SATS research will integrate the graphically intuitive, perspective depiction of flightpath guidance based on Highway in the Sky (HITS) Phase II products of the AGATE Alliance to create virtual skyways for enroute and terminal procedures. The SATS Program will integrate the enhanced vision and HITS technologies to meet the aggressive cost goals for SATS aircraft.
- Enhanced Vision: SATS will apply onboard sensor-based and/or database-generated depiction of terrain and obstacles in artificial or synthetic vision formats which are under development in the Aviation Safety Program and SATS-related Small Business Innovation Research (SBIR) projects. The SATS Program will invest in the integration of these technologies to meet aggressive cost goals for SATS aircraft.

The SATS Proof of Concept Program will consist of a set of experiments (simulation and flight) for each of the three operational capabilities. The research efforts will develop and demonstrate these operating capabilities in cooperation with the FAA and industry, state, and university partners. The experiments will be conducted to produce data to satisfy a set of exit criteria agreed upon by NASA and the FAA for the proofs of the three operating capabilities.

V. Program Assessment Metrics

The SATS Program assessment and metrics management process will include a systems engineering-based modeling and analysis effort. Progress toward the goal of reduced inter-city travel time will be measured using a matrix of transportation missions encompassing representative origin-destination sets, mission purposes, and transportation modes. The proposed metric for benchmarking and analysis is $[(\text{trip} \cdot \text{mph}) / \text{cost}]$. A trip is a person, group of persons, package(s), or service making a defined trip in the matrix. The mph or speed term is computed based on the doorstep to destination time and great circle distance traveled, including intermodal time requirements. The cost includes vehicle and infrastructure costs as well as the cost or value of time. The metric will be benchmarked using existing modes of travel for trips in the mission matrix. This benchmark will include the doorstep-to-destination inter-city travel times as well as costs for travel in the matrix. In addition to the time reduction goal, a cost goal will be set for travel in the matrix. That cost goal will include the cost of the vehicle, training, infrastructure and operations. The cost goal will be set at an aggressive level as a means of forcing technology investment decisions through a

rigorous decision-making process. Technologies will be forced to buy their way into the vehicle or the system based on their ability to meet the cost metric.

VI. Summary

For public stakeholders in the states and airport communities, the SATS experiments and the data collected will be designed to demonstrate that SATS capabilities significantly increase affordable access to virtually all communities, including rural and remote areas. For the FAA, the SATS demonstration would illustrate airborne technology-based approaches for increasing NAS capacity, for lower costs for NAS expansion, and for greater NAS throughput. In addition, the SATS demonstration will show that the distributed nature of SATS augments air carrier hub and spoke operations by accessing untapped NAS capacity. Finally, for industry customers, the experiments will illustrate the role of human-aiding automation in creating single-crew mission safety and reliability comparable with two-crew operations. These results of the five-year proof of concept Program will establish the basis for decisions by industry, the FAA, NASA, and the state and community decision-makers.

For more information visit the following websites:

<http://sats.nasa.gov>
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